IMPLEMENTATION OF INTEGRAL CONTROL STATE FEEDBACK CONTROLLER ON PRASMATIC CONTROL OF UNIVERSAL STRECH AND BENDING MACHINE (USBM) SIMPLIFIED MODEL

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ABSTRACT

This project presents the ability of pneumatic cylinder for controlling the prasmatic movement using implementations of Programmable Logic Controller (PLC). The design and modeling for pneumatic cylinder position control is using State-Space technique. A mathematical model of the system can be derived and verified by using SIMULINK/MATLAB. It is important to verify simulation result through experiment and compare it with expected result. As we know, many functions can be implemented using Programmable Logic Controller (PLC). PLC also can integrate with pneumatic valve in order to design a controller. The aim of this project is to implement integral Control State Feedback controller algorithm (controlling prasmatic movement of pneumatic valve) by using PLC. The controller algorithm that has been chosen is Integral Control State Feedback Control of Universal Stretch and Bending Machine (USBM) Simplified Model. This system using two input and one output which are set point and feedback sensor as their input and the movement of cylinder pneumatic is their output.

ABSTRAK

Projek ini berkisar berkenaan dengan kebolehan silinder pneumatik untuk mengawal pergerakan mendatar dengan mengimplimentasikan *'Programmable Logic Controller (PLC)'*. Model yang direka untuk silinder pneumatik ini adalah dengan menggunakan teknik *'State-Space'*. Model matematik untuk sistem boleh di hasilkan ataupun disahkan dengan menggunakan SIMULINK/MATLAB. Tujuan mengesahkan keputusan simulasi adalah penting melalui eksperimen dan membandingkannya dengan keputusan yang sepatutnya. Seperti yang diketahui umum, pelbagai fungsi boleh digunakan dengan menggunakan *'Programmable Logic Controller (PLC)'*. *PLC* juga boleh dihubungkan menggunakan *'pneumatic valve'* dalam rangka untuk menghasilkan pengawal. Tujuan utama projek ini adalah untuk mengimplimentasikan *'Integral Control State Feedback'* pengawal perubahan (mengawal pergerakan mendatar *'pneumatic valve'*) menggunakan *PLC*. Pengawal pembolehubah yang dipilih adalah '*Integral Control State Feedback Control of Universal Stretch and Bending Machine (USBM)'* model yang ringkas. Sistem ini menggunakan dua input dan satu output yang mana *'set point'* dan respon daripada sensor digunakan sebagai input manakala bagi output pula adalah pergerakan silinder pneumatik itu sendiri.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL

p	-	Input
q	-	Output
V	-	Voltage
i	-	Current
A	-	Ampere
K	-	Gain

LIST OF ABBREVIATION

I/P	-	Input
O/P	-	Output
PLC	-	Programmable Logic Controller
DC	-	Direct Current
ICSF	-	Integral Control State Feedback Controller
DDC	-	Direct digital control
USBM	-	Universal Stretch and Bending Machine

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

A programmable logic controller (PLC), or programmable controller is a digital computer used for automation in industrial processes, such as control of machinery on factory assembly lines. Unlike general-purpose computers, the PLC was designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. A PLC is an example of a real time system since output results must be produced in response to input conditions within a bounded time, otherwise unintended operation will result.[7]

Pneumatic cylinder systems have the potential to provide high output power to weight and size ratios at a relatively low cost. Its simple structure, easy maintenance, and low component cost, make pneumatic actuator one of the most employed industrial actuators. However, the complexity of the electro pneumatic systems and the important range of control laws are a real problem in the industrial field, when one has to choose the best control strategy for a given application.

Full state feedback (FSF), or pole placement, is a method employed in feedback control system theory to place the closed-loop poles of a plant in pre-determined locations in the s-plane. Placing poles is desirable because the location of the poles corresponds directly to the values of the system, which control the characteristics of the response of the system.[6]

As we know, many functions can be implemented using Programmable Logic Controller (PLC). PLC also can integrate with pneumatic valve in order to design a controller. The aim of this project is to implement integral Control State Feedback controller algorithm (for controlling prasmatic movement of pneumatic valve) by using PLC. The controller algorithm that has been chosen is Integral Control State Feedback Controller of Universal Stretch and Bending Machine (USBM) Simplified Model. The general concept for this project can be seen from the model of closed loop system in figure 1.1 below :

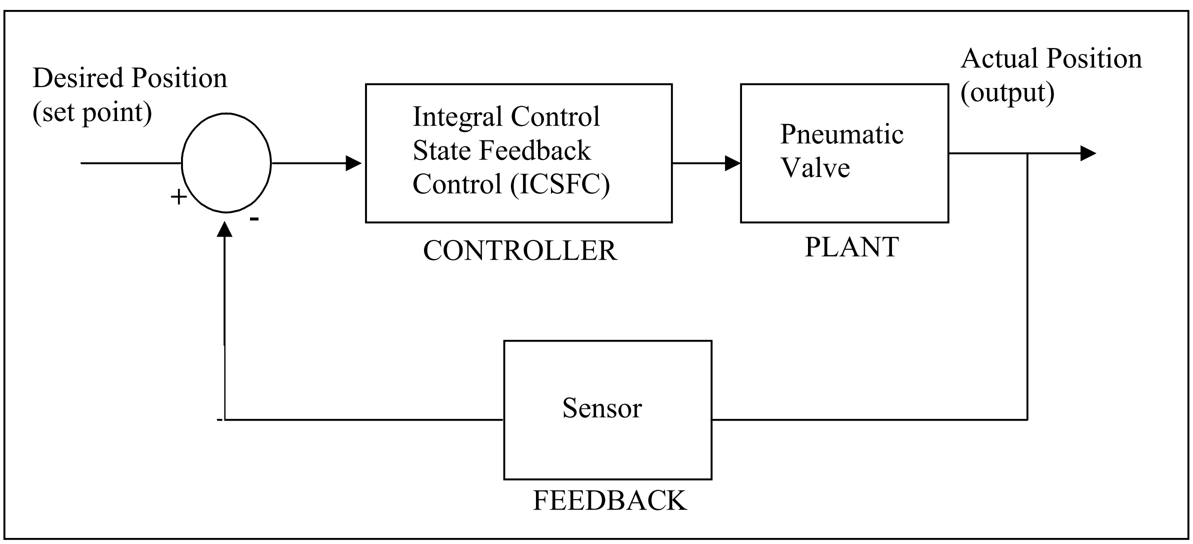

Figure 1.1: State Feedback Control Model

1.2 Problem Statement

Machines are easily damaged without implementation of control methodology in its system. Frequently, the desired performance characteristics of control systems are specified in terms of transient response. The transient response of a practical control system usually exhibits damped oscillation before reaching steady state condition. As for machines, having a high overshoot is an undesired condition since the starting current is very high. Thus, control methodology such as State Feedback controller is used to limit the maximum overshoot as well as to reduce the starting current of the machine. Therefore, the power consumption can be reduced as well as providing protection to machine from damage due to bad system performance.

Pneumatic cylinder can be controlled by PLC itself without applying State Feedback method. However, it is inefficient and having slow response system as desired output is normally hard to achieve. Thus, State Feedback method is implemented as a control methodology to obtain precise numerical information input, and yet capable of highly adaptive control.

Inefficiency of using on/off in controlling machine tools especially in big industries. In past, human operators are the main methods of controlling system. However, this system is hard to be applied especially in a big plant of industries.

1.3 Objective of the Project

- To design an Integral Control State Feedback Controller of Universal Stretch and Bending Machine (USBM) Simplified Model for implementation using Programmable Logic Controller (PLC) for controlling the prasmatic movement of pneumatic valve.

- To study the performance and reliability of the designed controller.
- To verify the simulation result through experiment.

1.4 Project Scope

This project is to design a State Feedback controller that can be used to control the algorithm (controlling prasmatic movement of pneumatic valve) by using PLC. As a machine's performance is a vital factor for a big production line, this project will examine the efficiency and performance of a pneumatic cylinder with implementation of control methodology. Thus, the focuses of this project are as stated below:

- To implement the controller by using PLC.
- To verify simulation result through experiment and compare it with expected result.

1.5 Thesis Outline

This thesis is composed of five chapters covering introduction, literature review, methodology, analysis and result and the last chapter is a conclusion and recommendation in future work.

Chapter 1 explains the background of the project, problem statements, objective and also the scopes. Pneumatic cylinder movement algorithm, State Feedback controller and PLC are the main essential in this project.

Chapter 2 focused on the literature review for those three parts that has been explained in Chapter 1. All the journals and books that are related to this project are used as a reference to guide and help completing this project. Each of this part is explain based on this finding.

Chapter 3 explains and discuss about the methodology that has been used in order to complete this project. There are two parts in this chapter which are the software development and hardware implementation. The discussion will be focusing on how to program the PLC and hardware integration.

Chapter 4 gives a detail result and analysis on the design aspects for the systems, which consists SIMULINK of State Feedback Controller using MATLAB®SIMULINK. Meanwhile discusses the design and development of the State Feedback controller on ladder diagram.

Chapter 5 discussed the conclusion of development of this project. This chapter also discusses the recommendation for this system for future development or modification.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

This chapter focused on the literature review for each component in this project. All the component is described in details based on the finding during the completion of this project.

2.2 State Space Controller

In control engineering, a state space representation is a mathematical model of a physical system as a set of input, output and state variables related to first-order differential equations. To abstract from the number of inputs, outputs and states, the variables are expressed as vectors and the differential and algebraic equations are written in matrix form (the last one can be done when the dynamical system is linear and time invariant). The state space representation (also known as the "time-domain approach") provides a convenient and compact way to model and analyze systems with multiple inputs and outputs. With p inputs and q outputs, we would otherwise have to write down $q \times p$ Laplace transforms to encode all the information about a system. Unlike the frequency domain approach, the use of the state space representation is not limited to systems with linear components and zero initial conditions. "State space" refers to the space whose axes are the state variables. The state of the system can be represented as a vector within that space.[6] The figure 2.1 show the typical state space model for the controller, where B is "input matrix", D is "feed through (or feed forward) matrix", A is "state matrix" and C is "output matrix".

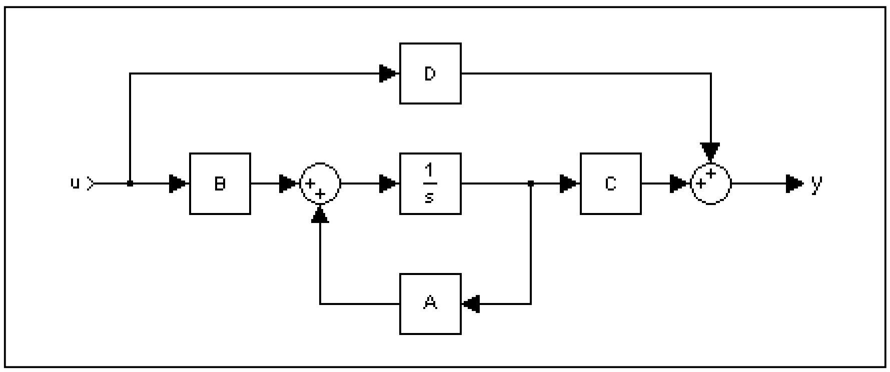

Figure 2.1: Typical state space model

The internal state variables are the smallest possible subset of system variables that can represent the entire state of the system at any given time. State variables must be linearly independent; a state variable cannot be a linear combination of other state variables. The minimum number of state variables required to represent a given system, n, is usually equal to the order of the system's defining differential equation. If the system is represented in transfer function form, the minimum number of state variables is equal to the order of the transfer function's denominator after it has been reduced to a proper fraction. It is important to understand that converting a state space realization to a transfer function form may lose some internal information about the system, and may provide a description of a system which is stable, when the state-space realization is unstable at certain points. In electric circuits, the number of state variables is often, though not always, the same as the number of energy storage elements in the circuit such as capacitors and inductors.[6]

Direct digital control (DDC) is one form of the automatic control where DDC is termed as using a digital computer to interface directly with a plant or system as the control device. The disparity between DDC and indirect digital control (supervisory control) is it does not require any additional hardware to implement the controller. Everything from controller's algorithms or structures in terms of codes and scripts can be manipulated and constructed inside the computer by the help of software.[3]

In designing the controller structures, full-state feedback with and without integral control where pole placement design via Bass and Gura's approach is proposed. The full state Feedback controller via pole placement is chosen since it has the best performance compared to other controllers in terms of oscillation and settling time. Moreover, the pole-placement design could also handle systems with time-varying state space representation or systems with multiple operating conditions, as well as systems with multi-inputmulti-output (MIMO) signals requirement.[3]

2.3 Programmable Logic Controller (PLC)

A programmable logic controller (PLC), or programmable controller is a digital computer used for automation of industrial processes, such as control of machinery on factory assembly lines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. A PLC is an example of a real time system since output results must be produced in response to input conditions within a bounded time, otherwise unintended operation will result.[7]

2.3.1 Advantages Using PLC

- Complexity – Much less complex than large relay based system
- Modularity – Very flexible due to network architecture
- Documentation – Virtually self-documenting
- Resource limitations – Very space efficient and less manpower required to install
- Cost and schedule – Up front material costs are similar, but savings on installation, maintenance, and troubleshooting increase rapidly as system size increases
- Reliability – Industry and lab experience demonstrate PLCs comparable to relay system
- Familiarity – Huge knowledge base in industry
- Training – Short learning curve for hardware and programming
- Troubleshooting – Ability to monitor every sensor speeds debug and repair

2.3.2 PLC compared with other control systems

PLCs are well-adapted to a range of automation tasks. These are typically industrial processes in manufacturing where the cost of developing and maintaining the automation system is high relative to the total cost of the automation, and where changes to the system would be expected during its operational life. PLCs contain input and output devices compatible with industrial pilot devices and controls; little electrical design is required, and the design problem centers on expressing the desired sequence of operations in ladder logic (or function chart) notation. PLC applications are typically highly customized systems so the cost of a packaged PLC is low compared to the cost of a specific custom-built controller design. On the other hand, in the case of massproduced goods, customized control systems are economic due to the lower cost of the components, which can be optimally chosen instead of a "generic" solution, and where the non-recurring engineering charges are spread over thousands or millions of units.[7]

A microcontroller-based design would be appropriate where hundreds or thousands of units will be produced and so the development cost (design of power supplies and input/output hardware) can be spread over many sales, and where the end-user would not need to alter the control. Automotive applications are an example; millions of units are built each year, and very few end-users alter the programming of these controllers. However, some specialty vehicles such as transit busses economically use PLCs instead of custom-designed controls, because the volumes are low and the development cost would be uneconomic.

Very complex process control, such as used in the chemical industry, may require algorithms and performance beyond the capability of even high-performance PLCs. Very high-speed or precision controls may also require customized solutions; for example, aircraft flight controls. PLCs have similar functionality as Remote Terminal Units. An RTU, however, usually does not support control algorithms or control loops. As hardware rapidly becomes more powerful and cheaper, RTUs, PLCs and DCSs are increasingly beginning to overlap in responsibilities, and many vendors sell RTUs with PLC-like features and vice versa. The industry has standardized on the IEC 61131-3 functional block language for creating programs to run on RTUs and PLCs, although nearly all vendors also offer proprietary alternatives and associated development environments.[7]

2.4 Pneumatic Cylinder

The pneumatic cylinder is the most common actuator in industry. The traditional cylinder is a cheap and simple component compared with other electromechanical actuators of equal power density. However it is not competitive in applications where demands on accuracy, versatility and flexibility are important.[5]

The main disadvantages of the pneumatic servo positioning systems are that, they are inherently nonlinear, that the compressibility of air results in very low stiffness (compared with the hydraulic system) leading to low natural frequency, and that low damping of the actuator system makes it difficult to control, especially with the presence of nonlinearities, time varying effects and position dependence.[5]

Pneumatic cylinder systems have the potential to provide high output power to weight and size ratios at a relatively low cost. Its simple structure, easy maintenance, and low component cost, make pneumatic actuator one of the most employed industrial actuators. However, the complexity of the electro pneumatic systems and the important range of control laws are a real problem in the industrial field, when one has to choose the best control strategy for a given application.

The two differential pressure sensors are used for measuring the pressure difference between the chambers of the cylinder; which is proportional to the driving force. The position sensor is non-contacting eddy current sensor with a range of about 2 mm and is used for measuring the pre-sliding displacement. (The cylinder is equipped with an integrated ultrasonic position sensor that is, however, not used in these experiments owing to its limited resolution). The acceleration is measured by a carrier signal, in- ductive accelerometer, with frequency range of 0-250 Hz. The velocity is then obtained by integrating the acceleration. A computer is used for providing the driving input voltage to the valve by means of a D/A converter and reading the transducers by means of AID converters.[5]

In this literature review, [4],[1] & [2] there are focusing about the advantages of using pneumatic servo system. Many researchers have investigated pneumatic servo systems due to their potential as a low-cost, clean, high power-to-weight ratio actuator. The compressibility of the working medium, air, and the large static and Coulomb friction continue to make achieving accurate position control a challenging problem.[4]

During the past decade, many pneumatic-servo systems have been used in automation industry mainly limited in “point-to-point” positioning control. They are clean, easy to work with, and lightweight. It is difficult for pneumatic-servo system to track the position continuously because of the substantial nonlinearities of air compressibility valve dead zone and saturation and cylinder friction.[1]

Servo pneumatic systems play an indispensable role in industrial applications thanks to their variety of advantages like simple operation, clean, low cost, high speed and easy maintenance. The dynamics of these systems are highly nonlinear and their models inevitable contain parametric uncertainties and unmodeled dynamics. The pneumatic servo system is a very nonlinear time-variant control system because of the compressibility of air, the friction force between the piston and the cylinder, energy and thermal effects inside the cylinder, the flow rate through the servo valve, etc.[2]

Servo electrical drive systems have been dominated up to the present time in the continuous position tracking.[1] Due to their high power-to-weight ratio and low cost, pneumatic actuators are attractive for robotics and automation applications; however, achieving fast and accurate control of their position have been known as a complex control problem.[2]

CHAPTER 3

METHODOLOGY

3.1 Introduction

There are important to determine the methodologies in order to develop this project to make sure this project can be finished according to the guidelines and still on the track especially for the objectives and scope of the project. Methodologies also the step from the beginning what actually this project are required and the step to divide part by part such as in developing software and hardware. The figure 3.1 below show the block diagram for the whole system of this project and simple explanation how it operates.